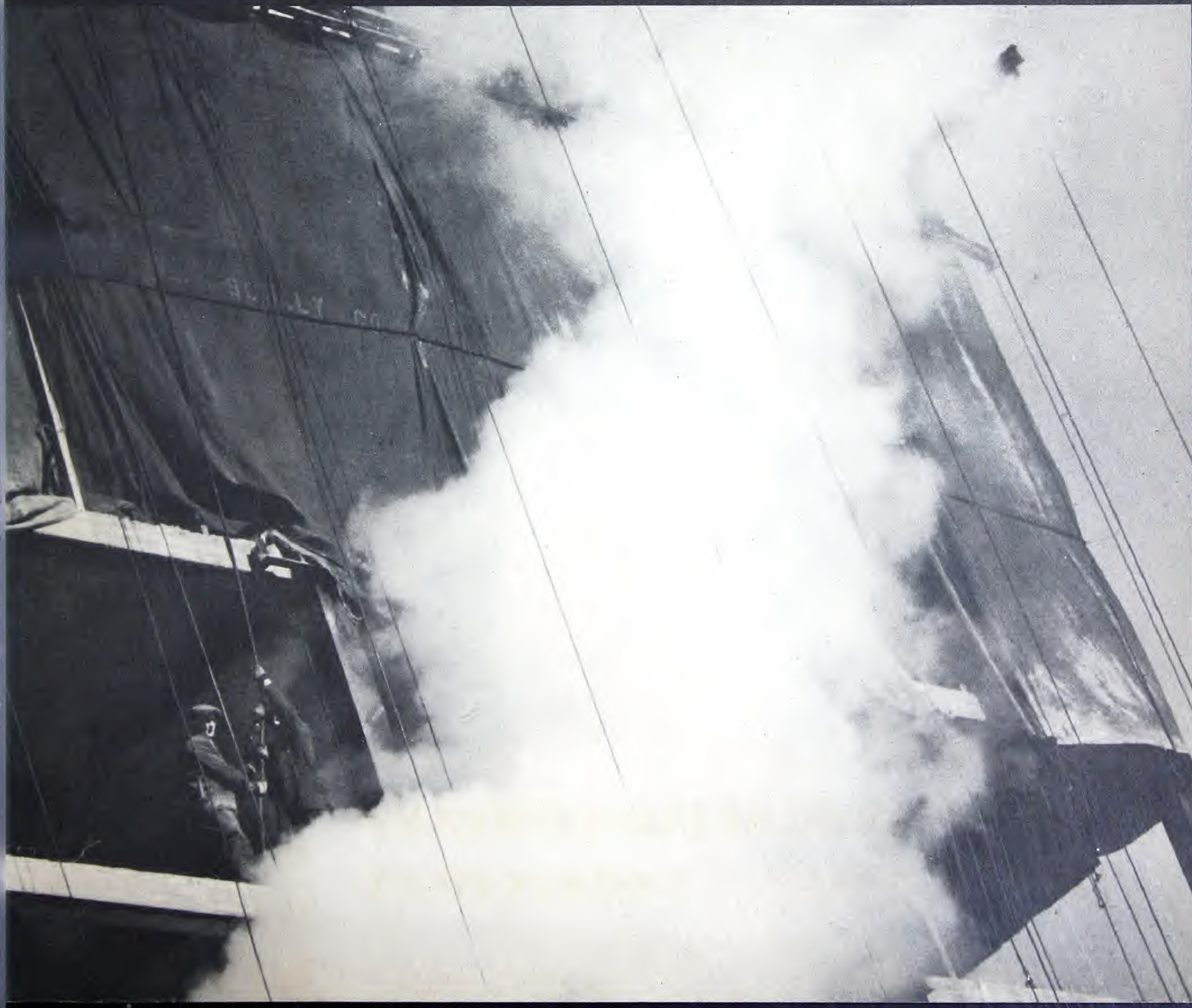
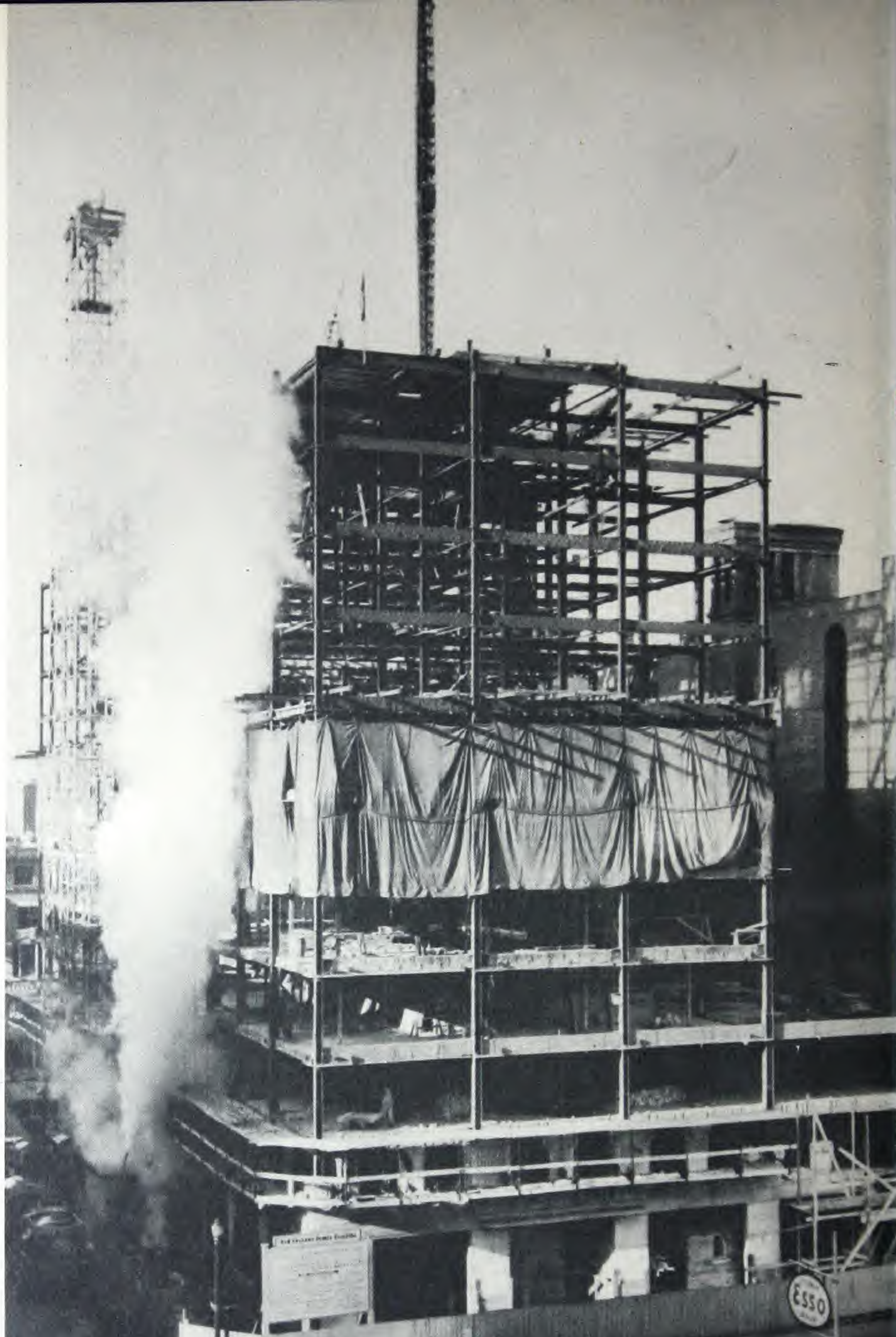
COLD-WEATHER CONCRETING



SAVED, $1.22 PER CU. YD. OF CONCRETE: Concreting Boston's 11-story New England Power Co. building started December 15, was finished February 1 —better than 1½ floors a week. 'Incor's dependable high early strength produced 3 savings: (1) one day's heat protection on each pour, cost $67.63 for fuel and fire-tending labor, or $1623 on 24 pours; (2) one form set, cost $2500; (3) job finished 15 days sooner, with job overhead $162 a day, meant $2430 saving. Total 'Incor' saving, $6553. Less extra cost of 'Incor', $1900. Net saving, $4653—or $1.22 a cu. yd. of concrete. Illustrates advantage of figuring most economical way to build each job. Read details on following pages.



LONE STAR CEMENT CORPORATION

MAKERS OF LONE STAR CEMENT...'INCOR' 24-HOUR CEMENT

General Offices: 342 MADISON AVE., NEW YORK . . . *Sales Offices:* ALBANY BIRMINGHAM BOSTON CHICAGO DALLAS HOUSTON INDIANAPOLIS KANSAS CITY NEW ORLEANS NEW YORK NORFOLK PHILADELPHIA ST. LOUIS WASHINGTON, D. C.

IF DEPOSITED AND MAINTAINED AT 70°, CONCRETE HARDENS JUST AS RAPIDLY IN WINTER AS IT DOES IN SUMMER . . . COSTS ARE REDUCED BY PROPER SELECTION AND PROPORTIONING OF MATERIALS . . . HIGH EARLY STRENGTH A FACTOR . . . HOW TO FIND THE MOST ECONOMICAL CONSTRUCTION METHOD FOR A GIVEN JOB.

MINIMIZING WINTER COSTS

IN Winter, construction lags. The contractor's organization is scattered; his investment in plant and equipment 'eats its head off.' The industry has to earn a year's income in eight or nine months. That penalizes everybody—owner, contractor, labor.

All stand to gain by year-around building. More contractors are available in winter to figure and bid. Skilled labor is abundant. Peak-season delays are largely eliminated. Modern methods and materials minimize excess winter costs. So, instead of waiting for the open season, there is every reason to build when structures are needed.

Winter Concreting Practical

Concrete work in particular used to be highly seasonal. Slow hardening cement retarded job progress. High winter-concreting costs often made it necessary to wait for 'building weather.'

That condition no longer exists. All cements now harden more rapidly. Lone Star Cement, cured at 70°, attains service strength in 3 to 5 days—'Incor' 24-Hour Cement in one day. If deposited and maintained at or about this temperature, *concrete hardens at the same rate in winter as it does in summer.*

How Cold Affects Strength

Of course concrete hardens slower when exposed to cold. As concrete temperatures fall, the chemical reaction between cement and water is retarded; at or about freezing, it practically stops.

In early Fall, concrete leaves the mixer at a temperature of about 45°. Hardening, slow at the start, is further retarded by cold nights.

Even when placed at 50° and exposed to 50°, concrete develops less than one-half of its normal strength at early ages, and at 28 days is still substantially below its 70° strength. At or about freezing, early strengths are less than one-quarter of normal, and concrete is exposed to the danger of frost damage.

Yet, it is entirely practical to protect the concrete so that it will harden at a normal rate, even at sub-freezing temperatures. Proper selection and proportioning of materials, to-

Three-inch thick shell of 'Incor' concrete, placed with cement gun over wooden frame, forms dome, 80′ in diameter, of New York's Hayden Planetarium (left). Concreted in November, 'Incor' attained working strength with minimum heat protection. Loss of material from re-bound, was negligible, because an 'Incor' mix hangs together better.

gether with adequate heat protection, furnish a simple solution.

Better Mixes Pay in Winter

Table I gives mix proportions and quantities of materials per cubic yard of concrete for a range of mixes containing from 5 to 8 gal. of water per bag of cement. Three consistencies are shown for each water content, of both Lone Star and 'Incor.'

Obviously, a mix must be selected with a workability adapted to job conditions, and one that will gain service strength fast enough so that the total cost of cement, placing labor and heat is a minimum. The more water the mix contains, the longer it takes to gain service strength and the greater the cost of heat protection.

Why Concrete Is Heated

Strengths shown in Table I are for 70° moist curing. But, as temperatures fall, hardening is retarded. Supplying heat during the initial

TABLE I: MIX PROPORTIONS, QUANTITIES AND STRENGTH

Total Water in Mix gal. per bag Cement	Slump in.	Approximate Mix by dry Volumes	Quantities per Cu. Yd.			Compressive Strength lb. per sq. in. Cured Moist at 70° F.							
			Cement bags	Sand* lb.	Gravel* lb.	'INCOR'				LONE STAR			
						1d	3d	7d	28d	1d	3d	7d	28d
	2	1:1¾:3¼	6.6	1090	2140								
5	4	1:1½:3	7.2	1010	2100	3050	4150	4800	5700	1400	2700	3550	4850
	6	1:1¼:2¾	7.8	940	2050								
	2	1:2¼:4	5.3	1240	2120								
6	4	1:2:3¾	5.8	1160	2090	2350	3400	3950	4800	950	2050	2750	3950
	6	1:1¾:3¼	6.4	1070	2050								
	2	1:3:4¾	4.5	1340	2090								
7	4	1:2½:4¼	4.9	1260	2060	1750	2700	3250	4050	650	1500	2150	3250
	6	1:2¼:3¾	5.4	1180	2030								
	2	1:3¾:5¼	4.0	1400	2050								
8	4	1:3:4¾	4.3	1340	2040	1250	2150	2650	3400	400	1100	1650	2600
	6	1:2¾:4½	4.6	1280	2010								

*Quantities of sand and gravel are based on dry materials. These quantities should be corrected for moisture and for specific gravities other than 2.65. Since these quantities are approximate, exact proportions should be established by trial batches.

TABLE II:
APPROXIMATE EFFECT OF TEMPERATURES ON COMPRESSIVE STRENGTH OF CONCRETE

'INCOR' 24-HOUR CEMENT

Temperature of Exposure °F.	Heat Protected 6 hr. at 70° F.				Heat Protected 1 day at 70° F.				Heat Protected 3 days at 70° F.			
	Compressive Strength—lb. per sq. in.											
	1d	3d	7d	28d	1d	3d	7d	28d	1d	3d	7d	28d
Total Water in Mix—5 gal. per bag of Cement												
70	3050	4150	4800	5700	3050	4150	4800	5700	3050	4150	4800	5700
60	2450	3600	4200	5050	3050	4000	4650	5500	3050	4150	4650	5600
50	1800	3000	3600	4400	3050	3800	4500	5300	3050	4150	4550	5400
40	1200	2350	3000	3700	3050	3650	4300	5050	3050	4150	4500	5300
30	650	1700	2250	2850	3050	3500	4050	4650	3050	4150	4400	5000
20	400	950	1300	1600	3050	3250	3600	4000	3050	4150	4300	4400
Total Water in Mix—6 gal. per bag of Cement												
70	2350	3400	3950	4800	2350	3400	3950	4800	2350	3400	3950	4800
60	1850	2750	3350	4100	2350	3250	3800	4600	2350	3400	3850	4600
50	1300	2250	2750	3450	2350	3100	3700	4350	2350	3400	3750	4500
40	850	1700	2200	2850	2350	2950	3450	4050	2350	3400	3650	4300
30	450	1200	1650	2100	2350	2800	3200	3600	2350	3400	3550	4000
20	250	700	850	1100	2350	2550	2750	3000	2350	3400	3400	3550
Total Water in Mix—7 gal. per bag of Cement												
70	1750	2700	3250	4050	1750	2700	3250	4050	1750	2700	3250	4050
60	1350	2200	2700	3400	1750	2600	3100	3850	1750	2700	3150	3900
50	950	1750	2200	2850	1750	2450	2950	3600	1750	2700	3050	3700
40	600	1350	1700	2300	1750	2300	2800	3300	1750	2700	2950	3500
30	300	950	1200	1550	1750	2200	2550	2900	1750	2700	2900	3250
20	150	500	600	750	1750	2000	2200	2300	1750	2700	2800	2900
Total Water in Mix—8 gal. per bag of Cement												
70	1250	2150	2650	3400	1250	2150	2650	3400	1250	2150	2650	3400
60	950	1700	2150	2800	1250	2050	2500	3200	1250	2150	2500	3250
50	650	1350	1700	2250	1250	1900	2400	2900	1250	2150	2400	3050
40	400	1000	1350	1800	1250	1800	2200	2650	1250	2150	2350	2900
30	250	700	950	1250	1250	1700	2000	2300	1250	2150	2300	2650
20	100	350	450	600	1250	1500	1650	1800	1250	2150	2200	2300

LONE STAR CEMENT

Temperature of Exposure °F.	Heat Protected 6 hr. at 70° F.				Heat Protected 1 day at 70° F.				Heat Protected 3 days at 70° F.			
	Compressive Strength—lb. per sq. in.											
	1d	3d	7d	28d	1d	3d	7d	28d	1d	3d	7d	28d
Total Water in Mix—5 gal. per bag of Cement												
70	1400	2700	3550	4850	1400	2700	3550	4850	1400	2700	3550	4850
60	1050	2150	2850	4000	1400	2550	3300	4450	1400	2700	3300	4500
50	750	1600	2250	3200	1400	2350	3050	4050	1400	2700	3100	4200
40	500	1200	1700	2400	1400	2150	2800	3550	1400	2700	2950	3850
30	300	850	1200	1750	1400	2000	2450	2950	1400	2700	2850	3400
20	150	400	550	700	1400	1800	2000	2150	1400	2700	2750	2900
Total Water in Mix—6 gal. per bag of Cement												
70	950	2050	2750	3950	950	2050	2750	3950	950	2050	2750	3950
60	700	1500	2150	3100	950	1900	2550	3500	950	2050	2600	3600
50	450	1100	1650	2400	950	1700	2300	3050	950	2050	2450	3250
40	300	800	1250	1850	950	1500	2000	2600	950	2050	2300	2900
30	150	550	900	1300	950	1350	1750	2200	950	2050	2150	2600
20	100	250	400	500	950	1200	1350	1500	950	2050	2050	2200
Total Water in Mix—7 gal. per bag of Cement												
70	650	1500	2150	3250	650	1500	2150	3250	650	1500	2150	3250
60	450	1100	1650	2450	650	1400	1950	2800	650	1500	2000	2850
50	300	800	1250	2000	650	1250	1750	2500	650	1500	1850	2600
40	200	600	950	1350	650	1100	1500	1950	650	1500	1700	2250
30	100	400	650	900	650	900	1200	1500	650	1500	1600	1900
20	50	150	300	450	650	750	850	1000	650	1500	1550	1600
Total Water in Mix—8 gal. per bag of Cement												
70	400	1100	1650	2600	400	1100	1650	2600	400	1100	1650	2600
60	250	800	1250	2000	400	1000	1500	2250	400	1100	1550	2350
50	150	550	950	1550	400	850	1250	1900	400	1100	1450	2000
40	100	400	700	1200	400	750	1050	1500	400	1100	1350	1700
30	50	300	500	800	400	650	850	1100	400	1100	1200	1450
20	20	150	250	350	400	500	550	650	400	1100	1150	1250

hardening stages enables the concrete to develop its early strength at a normal rate.

Table II indicates the effect upon strength when concrete is exposed to lower temperatures, after heat protection for various periods. Example:

A 6-gal. Lone Star mix, placed and maintained at 70° for 6 hours and then exposed to 30°, will have about 150 lbs. and 550 lbs. strength at 1 day and 3 days, respectively, and 1300 lbs. at 28 days.

The same mix, maintained at 70° for 24 hours, has its full one-day strength of 950 lbs.; at 3 days 1350 lbs., and about 2200 lbs. at 28 days. Protected for 3 days, this concrete will attain about 2000 lbs. the third day, and in excess of 2600 lbs. at 28 days. Thus, heat protection not only means higher strengths at early ages but at 28 days as well.

Heat curing is even more effective with 'Incor'. For a 6-gal. mix with 30° exposure, 6 hours' protection means about 450 lbs. at 1 day and 2100 lbs. at 28 days; while with one-day protection, full service strength of over 2000 lbs. is developed in 24 hours, and the 28-day strength is increased to 3600 lbs.

As shown by Table II, strengths are similarly affected with all mixes at sub-normal temperatures; but the better the mix, the more strength developed with a given amount of heat.

Minimizing Concrete Costs

Sufficient heat must be provided to protect the concrete from freezing—that is, until it

To permit steady job progress and provide continuous employment for labor, 'Incor' was used in concreting 4-million-gallon water purification plant at North Beverly, Mass. (left), as soon as cold weather set in. Air temperatures fell to zero, but work progressed without delay. 'Incor' minimized heat-protection costs and reduced form requirements. Concrete is strong, dense, watertight—in spite of difficult operating conditions.

gains a strength of say, 1000 lbs. *Is it cheaper to provide only enough heat to avoid freezing risk and then wait for service strength, or to give the concrete thoroughly adequate protection until service strength is attained?*

There can be no one answer that will fit all cases, because the problem involves the cost of protection itself, and the effect of strength-gaining time on job progress and fixed overhead costs.

If you provide only enough heat protection to safeguard against freezing and then wait for service strength, it takes longer to complete the job. Now it costs money—anywhere from $25 to $100 or more—every day the contractor is on a job, and this fixed job or overhead expense has to be figured in the cost comparison.

The cost of heat protection is made up of (1) cost of heating concrete aggregates (2) cost of enclosures and their handling, and (3) cost of supplying heat.

Temperature and exposure conditions govern the first two cost items; they are approximately the same, regardless of whether you cure merely for safety against freezing or for early service strength. *But the cost of supplying heat depends upon how long it takes the concrete to attain service strength; obviously, the quicker the concrete hardens, the shorter the heat-protection period and the lower this cost.*

However, if you increase the cement content of the mix, or if you use 'Incor', the cement cost is increased and has to be offset by a saving in heat-protection.

Typical Cost Comparison

To illustrate one method for finding the most economical concrete mix and heat-curing period, let us assume the construction of a concrete frame building, using values given in the box on this page.

Since variations in cost of materials, labor, fuel and time will affect the relative economy of the concrete mixes and curing periods, each job should be analyzed separately in order to find the most economical combination.

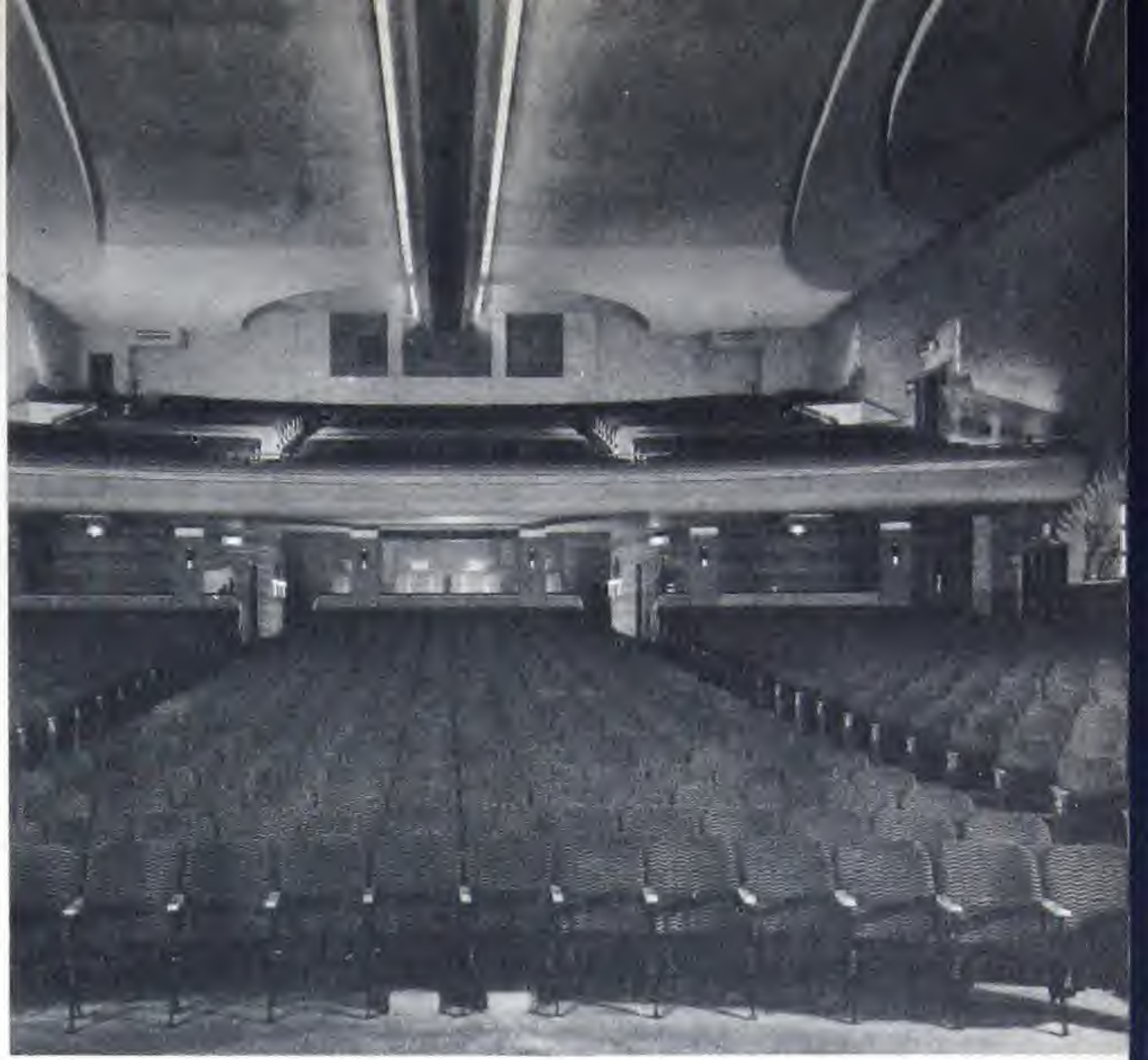
Economy requires the lowest total of the

BASIS OF COST COMPARISON

Assumed Data for Reinforced Concrete Frame Building

Plan:	**80′ x 125′**
Height:	**6 stories and roof**
Superstructure Concrete:	**1300 cu. yds.**
Cement:	**Lone Star Cement, $2.00 per bbl.** **'Incor' 24-Hour Cement, $2.50 per bbl.**
Heating Cost:	**At 50° Air Temperature—$50 per day** **At 20° Air Temperature—$75 per day**
Cost of Forms:	**$2,500 per floor**
Const. Schedule:	**5-day work-week** **For each floor:** **5 days to strip and reassemble forms, place steel and conduits.** **1 day to pour concrete.** **Curing period, according to concrete mix and heat protection.**

Behind-schedule construction on Washington's new Penn Theatre and approaching cold weather meant overtime, costly heat-protection—delayed opening, lost revenue. 'Incor' was used in the all-concrete balcony (right). District of Columbia Code specifies 21-day shore removal in Fall and Winter, but 'Incor' test cylinders, job cured at 51°, averaged 5-day strengths of 2160 lbs.—exceeding 28-day requirement. Result, riser forms stripped in 4 days, beams in 6 days—15 days saved.



following cost items:

1. *Cost of materials:* Changes in mix have little effect upon aggregate costs, so only cement cost per cubic yard is considered.
2. *Fuel and labor cost* for protecting concrete: All concrete in this illustration is deposited at 70°, so cost of heating aggregates is not included. The variable is in the cost of providing heat protection; that is, fuel cost and labor tending fires.
3. *Cost of forms:* Labor and material required for making up forms.
4. *Straight-time payroll and fixed charges*—which run on regardless of job progress.

Table I indicates that a slump of 6 inches and a 5 gal. mix requires 1.95 barrels of cement per cubic yard; 6 gal., 1.6 bbl.; 7 gal., 1.35 bbl. Thus, cement costs per cubic yard are as follows for conditions shown in the box:

Water per Sack of Cement	Cement Cost per Cu. Yd. Concrete	
	Lone Star Cement	'Incor' Cement
5 gal.	$3.90	$4.88
6 gal.	3.20	4.00
7 gal.	2.70	3.38

Costs and methods vary with air temperature. First, take a Spring or Fall condition with 50° average air temperature. Table II shows that with Lone Star eight combinations of water ratios and heating periods will develop 2000 pounds in less than 28 days, and with 'Incor' six will produce service strength in 5 days or less. So, the problem is to find the mix that produces the lowest total cost for Items 1, 2, 3 and 4.

Since a lean mix has a lower material cost but requires longer heat protection than a richer mix, the final choice will depend upon the time cost (straight-time payroll and fixed charges). If this cost is low, it may pay to use a leaner mix, supply minimum heat protection and wait for the concrete to gain service

Contractor switched to 'Incor' when cold weather delayed construction of retaining-wall foundation (left) for first of two additions to Inland Container Corp. plant, Indianapolis. Early service strength reduced frost hazard, speeded job progress; and 'Incor's greater workability reduced placing costs—more yardage placed and finished per day. In second addition, 'Incor' was used for basement, enabling contractor to quickly place heavy caterpillar crane for steel work.

strength. As time cost increases, it will usually pay to use a richer mix and protect sufficiently to develop service strength within a short time. Following table shows costs of cement and heat for the assumed building, and indicates the cheapest concrete mix and heat-protection period for three representative time costs:

50° EXPOSURE

W/R	Days Heat per Floor	Days for 2000 lbs. per sq. in.	Const. Time, Work. Days	Cement Cost 1300 cu. yd.	Heat Cost 7 Floors	Total Cost for Daily Time Value of $25	$50	$100
LONE STAR								
5 gal.	¼	5	66	$5070	—	$6720	$ 8370	$11,670
	1	3	51	5070	$350	6695	7970	10,520
6 gal.	¼	14	96	4160	—	6560	8960	13,760
	1	5	66	4160	350	6160	7810	11,110
	3	3	51	4160	1050	6485	7760	10,310
7 gal.	¼	28	156	3510	—	7410	11,310	19,110
	1	14	96	3510	350	6260	8660	13,460
	3	10	81	3510	1050	6585	8610	12,660
'INCOR'								
5 gal.	¼	2	46	6338	—	7488	8638	10,938
	¾	¾	42	6338	280	7668	8718	10,818
6 gal.	¼	3	51	5200	—	6475	7750	10,300
	1	1	42	5200	350	6600	7650	9,750
7 gal.	¼	5	66	4388	—	6038	7688	10,988
	1	2	46	4388	350	5888	7038	9,338

Of the Lone Star mixes, 6 gal. with one day heat curing is cheapest when time is worth $25 a day. But as the value of time increases, 3-day heat-curing with its 2-day saving per floor becomes most economical. The 7-gal. concrete, heat-cured one day, is the cheapest 'Incor' mix for all time values, and shows a lower cost than any Lone Star mix.

This example assumed that the concrete temperature was 70° when deposited, which means heating mixing water to a temperature of say 150° in cool weather. But if materials are not heated, and concrete is deposited at 50° and cured at 50°, time cost figures are as follows:

50° CONCRETE TEMPERATURE
50° AIR TEMPERATURE

W/R	Days for 2000 lbs. per sq. in.	Const. Time, Work. Days	Cement Cost 1300 cu. yd.	Total Cost for Daily Time Value of $25	$50	$100
LONE STAR						
5 gal.	7	66	$5070	$6720	$8370	$11,670
6 gal.	14	96	4160	6560	8960	13,760
7 gal.	28	156	3510	7410	11,310	19,110
'INCOR'						
5 gal.	2	46	6338	7488	8638	10,938
6 gal.	3	51	5200	6475	7750	10,300
7 gal.	7	66	4388	6038	7688	10,988

Comparing these figures with those in the preceding table, it is seen that for all time values it is cheaper to heat and protect concrete, than to place and cure it without heat protection, even at as mild a temperature as 50°. Risk of

Switching to 'Incor' during winter building of addition to Alton Box Board & Paper Company's Federal Ill., plant (below) produced three savings: (1) Form material was re-used in 24 hours, avoiding expense for two additional cars of form lumber; (2) 5 days' heating cost was saved on outside spandrel walls and concrete sills; (3) job finished 5 weeks sooner, saving that much overhead. In addition, plant operation was continuous—early working strengths avoided shut-down waiting for concrete to harden.

excessive delays from temperature drops is minimized by initial heating of the concrete.

Now, consider the same cost factors, with a winter air temperature of say 20°; all cost assumptions remain the same, except that heating cost is increased to $75 per day:

20° EXPOSURE

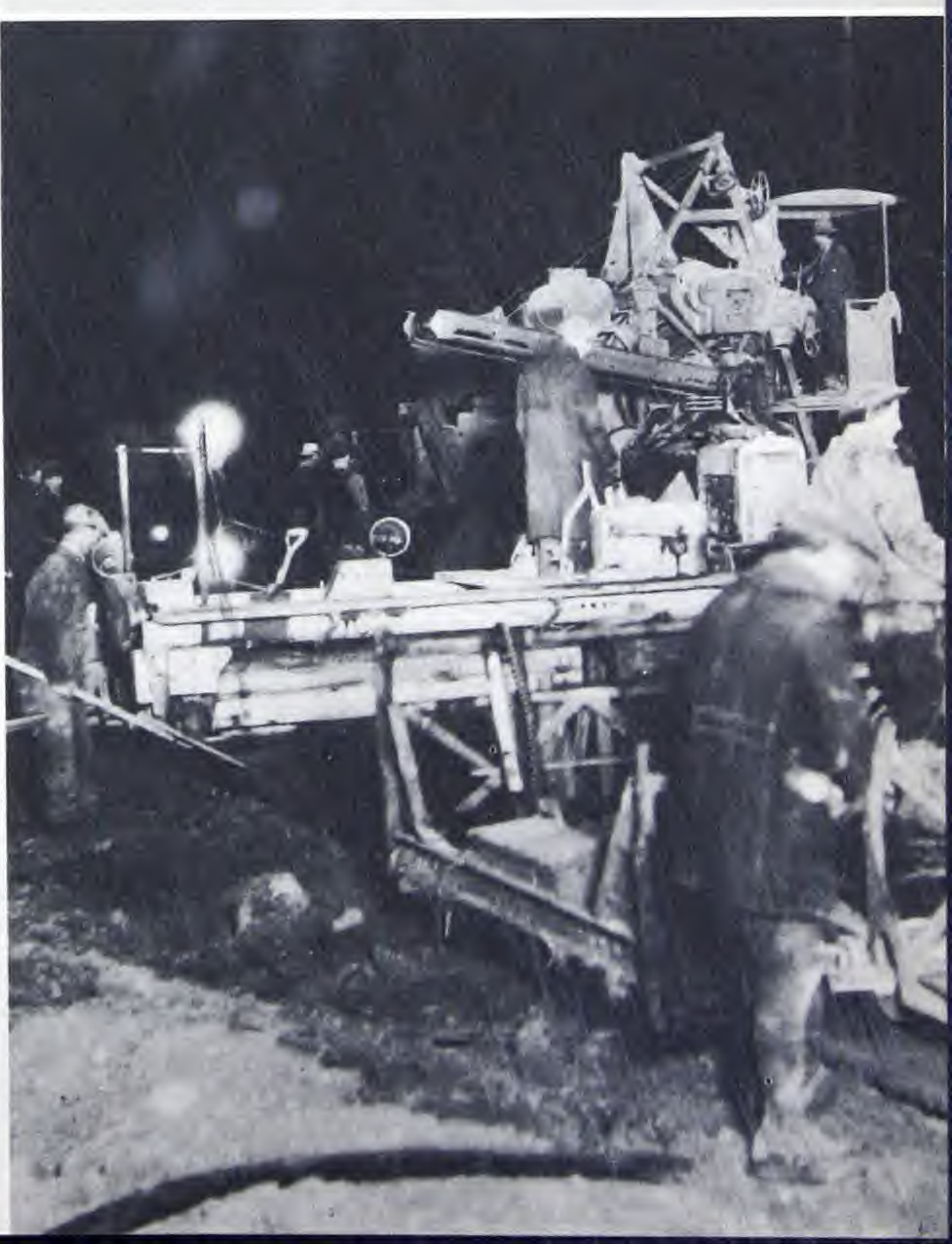
W/R	Days Heat per Floor	Days for 2000 lbs. per sq. in.	Const. Time, Work. Days	Cement Cost 1300 cu. yd.	Heat Cost 7 Floors	Total Cost for Daily Time Value of $25	$50	$100
LONE STAR								
5 gal.	1	10	81	$5070	$ 525	$7620	$9645	$13,695
	2½	3	51	5070	1330	7675	8950	11,500
6 gal.	3	3	51	4160	1575	7010	8285	10,835
'INCOR'								
5 gal.	¾	1	42	6338	525	7913	8963	11,063
6 gal.	1	1	42	5200	525	6775	7825	9,925
7 gal.	1	3	51	4388	525	6188	7463	10,013
	2	2	46	4388	1050	6588	7738	10,038

Note that lower temperatures eliminate the 7 gal. Lone Star mix and place a premium on full heat protection and short curing periods. For 'Incor', the 7 gal. 1-day heat-cured mix is cheapest at $25 and $50 per day time value. But when time costs approach $100 a day, the better 6 gal. mix becomes cheaper, because it produces service strength in less time. These figures illustrate the savings at low temperatures from heat curing until service strength is secured. Observe, also, that at all time values and at air temperatures of 20°, 'Incor' costs are lower than Lone Star costs and by a wider margin than is the case at 50°.

With slower schedules and two form sets, the cost of the extra form should be offset by

(Above) In paving Routes 28 and 50 through Milford, Ohio, plans provided for use of 'Incor' only at key points. But advantages of early service strength and minimized cold-weather hazard caused Highway Department Engineers to use 'Incor' on entire job. Water and aggregates were heated, freshly-placed concrete promptly protected with burlap and straw. 'Incor' test cylinders averaged 3827 lbs. at 5 days and 5655 lbs. at 28 days.

Resurfacing 1½-mile section of Hamilton-Eaton Road (right), in Ohio; concrete poured Dec. 5 to 30. Finished grading was carried only 500 ft. ahead of mixer, subgrade straw-covered at night, thawed out in morning with hot water and steam. Forms were pre-heated with steam and hot water; concrete placed on grade at 70°, covered with wet burlap and 10″ of straw, protected until 600 lb. beam-strength permitted opening. Beams, cores and cylinders from each day's pour were cured with pavement. 36 beams averaged 72-hour opening strengths, some in 48 hours. Temperatures reached sub-zero, but concrete was placed continuously. Dec. 26th night temperatures dropped to 7° below zero; next morning temperature under covering at concrete surface was 44°, air temperature 6° above zero. 'Incor' cores from that day's run developed 24-hour compressive strength 1509 lbs., 48-hour 2610 lbs.



a saving in time. Thus, a 10-day curing period requires 81 days to construct with one form set and 44 days with two, a difference of 37 days. As a set of forms will cost about $2500, time must be valued at more than $68 per day in order to make the second form set profitable. Let us now compare two such schedules with an efficient 'Incor' schedule at an air temperature of 20°.

ONE AND TWO FORM SETS
20° AIR TEMPERATURE

W/R	Days Heat per Floor	Days for 2000 lbs. per sq. in.	Const. Time, Work. Days	Cement Cost 1300 cu. yd.	Heat Cost 7 Floors	Cost Forms	Total Cost for Daily Time Value of $25	$50	$100
LONE STAR				ONE FORM SET					
5 gal.	1	10	81	$5070	$525	$2500	$10,120	$12,145	$16,195
LONE STAR				TWO FORM SETS					
5 gal.	1	10	44	5070	525	5000	11,695	12,795	14,995
'INCOR'				ONE FORM SET					
6 gal.	1	1	42	5200	525	2500	9,275	10,325	12,425

Observe that the schedule using 'Incor' is cheaper than that for Lone Star at all time values and for both one and two form sets.

General Conclusions

While variations in the cost of time, heating and other operations affect the relative economy of the various concrete mixes, conclusions may be drawn from the foregoing:

1. At sub-normal air temperatures, it pays to maintain concrete temperatures at 70°.
2. For air temperatures of 50° or lower, savings in time and heat protection result from the use of 'Incor' on light construction like buildings. At higher temperatures, and for mass work, Lone Star will frequently show a favorable cost comparison.
3. With low time values and mild temperatures, a leaner mix and minimum heat protection will usually show a profit; but as time values increase and temperatures approach freezing, it is best to use sufficient heat and a mix which will produce service strength within a short time.

These conclusions refer particularly to concrete frame construction, but the same principles apply in degree to the entire range of concreting work. This is illustrated by typical winter jobs shown on these pages, including not only buildings, but bridges, pre-cast products, sewers, watertight and other structures. It is well worth while to figure these economies on all types of concrete work—large or small.

(Below) Four of the 9 spans on Indianapolis Boulevard Viaduct, Hammond, Ind., were concreted after Nov. 1st. Sub-freezing temperatures and windswept location made thorough heat protection imperative. Heated ready-mixed concrete was placed at 75° to 80°. Steam jets supplied heat at top and bottom of slab. Windbreaks were hung from sidewalk brackets; top covering, suspended on wooden frames, consisted of a layer of tarpaulins, one of straw mats and a final layer of tarpaulins. Contractor switched to 'Incor' because State permitted reduction of heating period from 72 hours to 30 hours or until 400 lb. beam strength was attained. Contractor's heat-protection system was so well handled that as soon as beam breaks showed over 400 lbs., which was mostly the case in 24 hours, curing was discontinued, enabling him to reassemble steam lines on same afternoon for next morning's pour, saving overnight firing of boilers and one day's delay. Total saving, 2 weeks' boiler fuel and labor.

WINTER JOB PRACTICE

Protection of concrete in even the most severe weather is not difficult, once the principles are understood.

A fundamental of successful cold-weather concreting is prompt protection of freshly-placed concrete. Too often, protection starts only after the day's concreting is finished, usually late in the day with the thermometer dropping, resulting in the loss of much, if not all, of the initial heat. Strength is sacrificed and valuable time is lost. But concrete gains strength only when wet, so heat and moisture must go together. If dry heat is used, concrete must be wet down.

Nowhere else in the entire range of construction do sound methods and careful workmanship pay higher dividends than in sub-freezing concrete operations. Here the advantages of 'Incor' are clearly apparent. By providing 'Incor' with 1 to 3 day heat-curing, costly heat-protection will be reduced to a minimum. After heat-protection is finished, enclosures should be left in place while concrete cools to outside air temperatures. This cooling should cover a period of 2 to 3 days in extremely cold weather.

It is good practice to consult the nearest weather bureau and use their information as a guide in planning protection from day to day.

Adequate Heat Protection Important

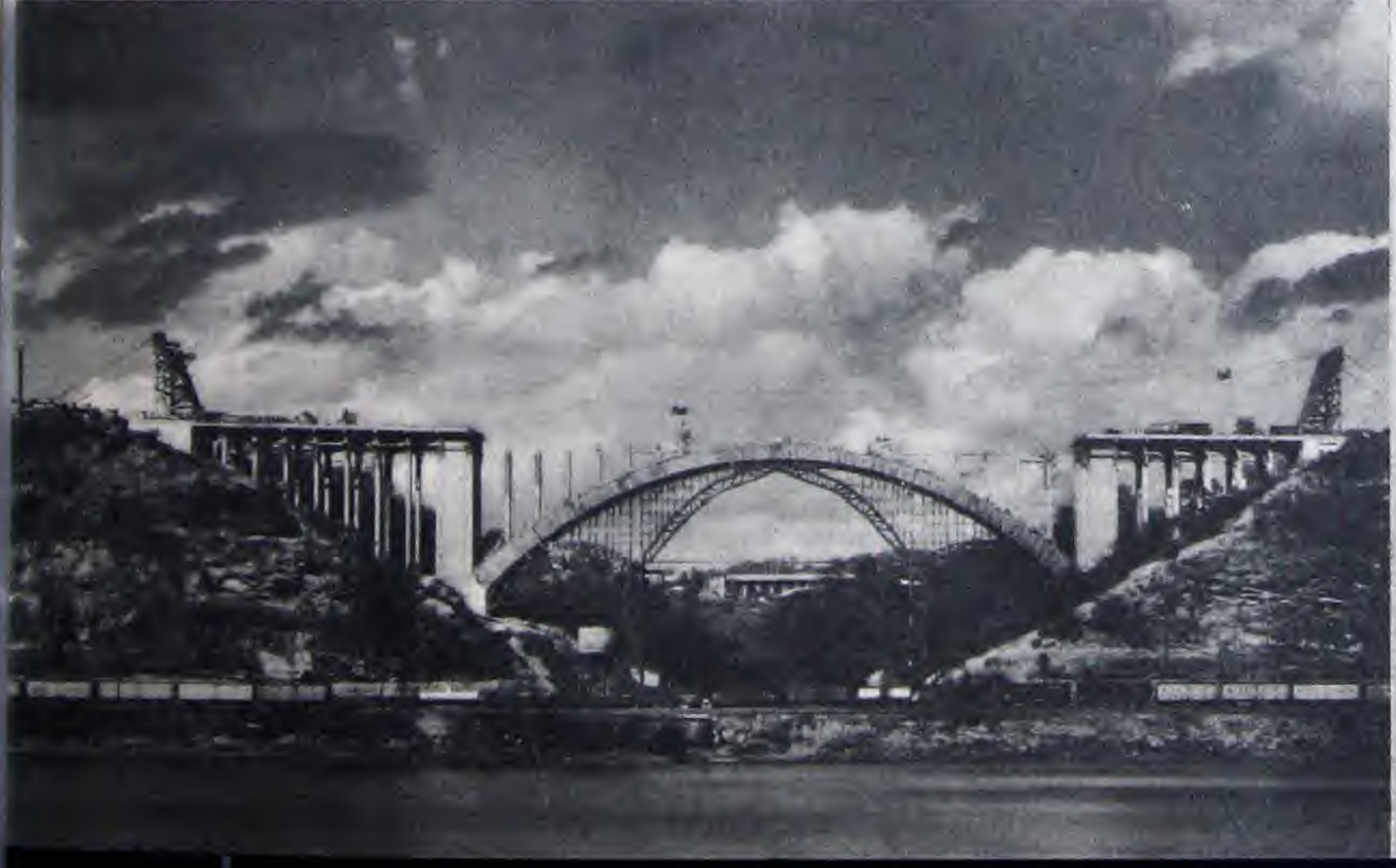
Heat protection methods depend upon air temperatures. For simplicity, sub-normal temperatures may be classified on the basis of mean temperatures from sunset to sunrise, as follows:

1. Cool—night temperatures average 50°.
2. Cold—night temperatures average 33°.
3. Sub-freezing—night temperatures average 16°.

Cool weather: In late Spring and early Fall, unheated concrete is cool when placed; if unprotected, it loses heat and hardens but little during the first night, the critical period for early strengths. Some precautions should be taken; usually it is sufficient to heat the mixing water and promptly protect the freshly-placed concrete.

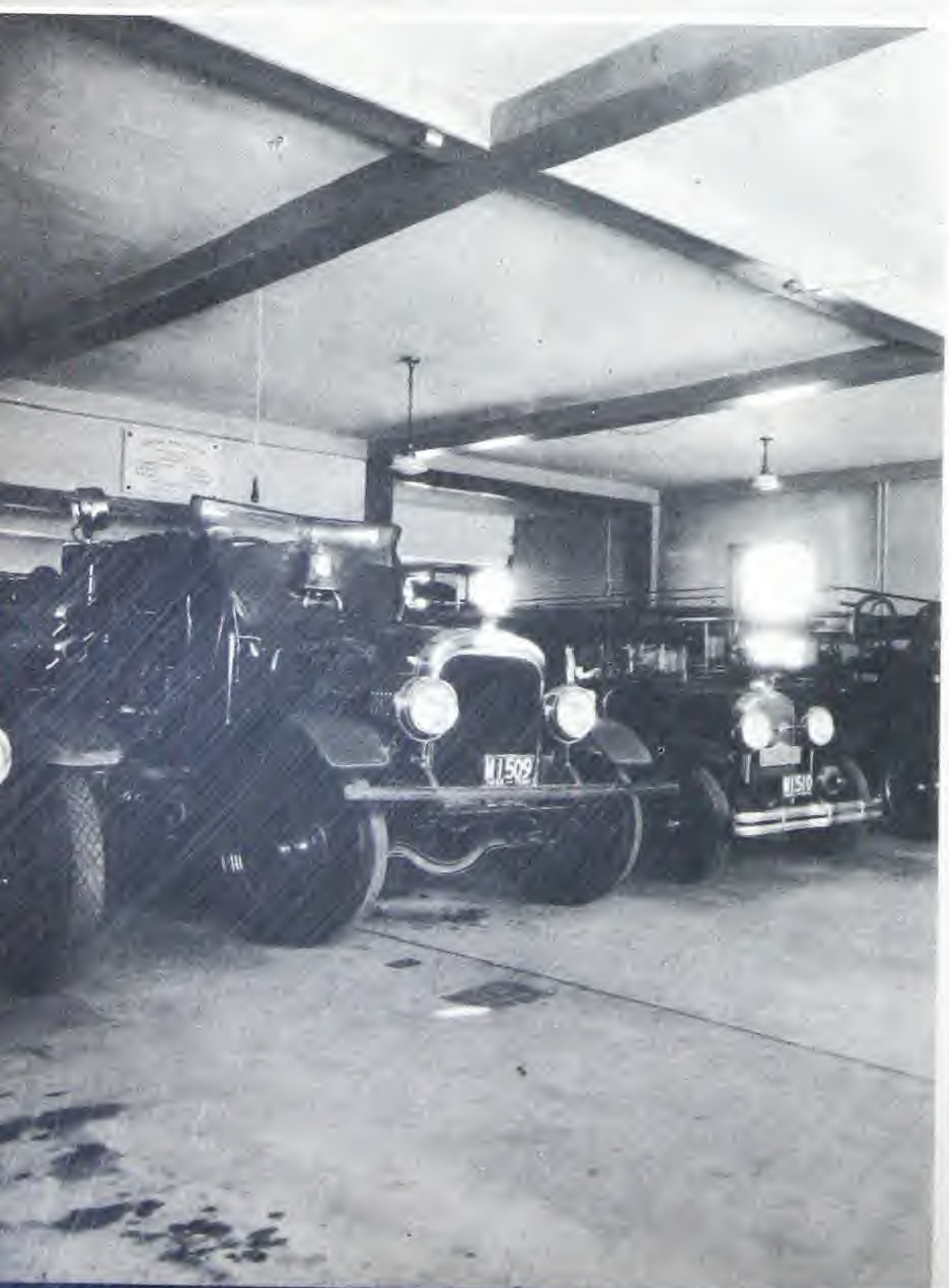
When mean night temperatures fall below 45°, additional precautions are necessary. Both mixing water and aggregates should be heated, the amount of heat depending upon exposure conditions. In all cases, be on the safe side—don't take chances.

Flat work, such as pavements and large masses,



Four-lane boulevard along Ohio River near Pittsburgh, required nine bridges in 3½ miles—five of them two-ribbed, reinforced-concrete arch structures. Contractor had two years to complete job. Original plans, calling for Summer bridge construction, interfered with grading and paving, so all bridges were built first Winter. Using 'Incor' in arch ribs, work progressed at Summer schedules in dead of Winter. Centering for two ribs was used in forming 10 ribs of the five concrete arch bridges. These two sets were combined to form the Jack's Run span shown at left. Only 2 days' steam curing was required—a 5-day saving on each arch rib. Centers were struck and arch ribs made self-supporting in 4 days, saving 10 days. Job completed 7 months ahead of schedule. Contractor estimates $20 saving for each dollar extra expended for 'Incor'.

Concrete retaining wall (above) on Merrimack River, Haverhill, Mass., was built in cold New England mid-Winter. Materials were heated, heat protection supplied for curing. 2° below zero when 'Incor' concrete was placed, temperature dropped to 20° below while curing. But in 48 hours 'Incor' was strong enough to resist freezing. Submerged by flood tides, exposed to freezing and thawing, this job is in excellent condition.



should be promptly and effectively covered. For structures above ground, apply heat inside the enclosure, preferably exhaust steam. Exposed surfaces, particularly angles, pilasters, lintels, buttresses, etc., should receive special attention.

Cold weather: Under cold weather conditions, it does not pay to maintain temperatures lower than 70° during curing; it is cheaper to maintain adequate heat for one day than inadequate heat for several days. If heat-protection is required, you might as well cash in on the ability of the cement to harden rapidly and produce service strengths at the earliest time.

Sub-freezing weather: When mean temperatures between sunset and sunrise are below freezing, more elaborate precautions are necessary: (1) Initial concrete temperatures should be sufficiently high so that a 70° temperature is retained by the concrete when covered; (2) more efficient protection is necessary to avoid heat losses; (3) higher concrete strengths must be secured to withstand the effect of freezing after heat-curing stops and to minimize heat-curing periods; (4) a cooling-off period of from 1 to 3 days should be provided after heating has stopped and before protective coverings are removed.

Summary of Winter Methods

Following is a summary of successful winter job practices:

1. ***Use a good mix:*** Follow sound concrete practice; use no more water than required by placing conditions. Lean, wet mixes gain strength slower, and hence are exposed to greater risk of freezing.

2. ***Heated mixing water:*** A 5° rise in temperature of mixing water produces a rise of approximately 1° in concrete temperature. Thus, if concrete temperature is to be raised 20°, without heating aggregates, water temperature should be raised 100°.

Water may be heated by exhaust steam released at the bottom of the tank, by steam coils, or by direct-fired boilers. It pays to have more than enough hot water; only a large reservoir can deliver water at uniform temperature.

A low-pressure boiler of ample size (mounted on skids if the mixer is moving), discharging into the measuring tank of the mixer, is desirable. Under severe conditions, it pays to protect the mixer tank.

During winter floor-replacement at Central Fire Station (left), Wakefield, Mass., apparatus had to be kept near fire-alarm system and could not be left outside to freeze. Slab was laid in three sections; while pouring one section, apparatus remained in place on other two. Outside air temperature 17° below zero, inside 45° above, one slab was poured January 26th, finished at 6 p. m. Forty-four hours later, at 2 p. m., January 28th, an aerial ladder, weight 4 tons on rear axle, rolled onto freshly-placed 'Incor' concrete without marring floor. And concrete cured thoroughly watertight—no leaks have appeared in spite of daily hose washing.

Excessive water temperatures should be avoided; 150° is a good working limit—never exceed 180°.

If water is heated above 150° (and in no case above 180°), put water and aggregates into the mixer first. Then, after the drum revolves a few times, add the cement. In this way, setting up of cement in the mixer will be avoided.

3. ***Heated aggregates:*** Aggregates should be heated to between 60° and 70°; dry heat and excessive temperatures should be avoided. The soundest method is to store the aggregate in compact piles, underlaid with perforated low-pressure steam pipes. Given sufficient time, the exhaust steam will raise aggregate temperature uniformly and drive out all frost. Heat all parts of the pile thoroughly; under severe conditions cover stock piles.

Be sure aggregates are fully heated when withdrawn from stock piles—systematic handling will prevent use of cold materials and minimize heat protection.

4. ***Thorough mixing:*** It pays to mix thoroughly; additional mixing permits the use of less water for a given workability, and that means increased concrete strengths.

5. ***Prompt placing:*** Concrete should be placed in forms at a temperature that will allow for heat losses before protection is applied, so that the concrete will always be maintained at 70° minimum temperature. Transportation from mixer to work should be studied. Move the concrete no further than necessary—avoid delays—guard against heat loss en route. Deposit concrete as near to final resting place as possible.

Spread, compact and finish concrete promptly—*then apply protection immediately.* Early strengths depend upon the speed with which concrete is protected—heat losses are highest during the first hour after placing.

6. ***Heat of hydration:*** All concrete generates heat, due to the hardening action of the cement; some cements generate this heat rapidly, others slowly.

This heat, if held in the concrete, greatly assists hardening. As much of its heat of hydration develops at early periods, prompt covering will retain this heat as well as that contained in mixing water and aggregates, and advance the hardening process.

7. ***Protection:*** Protection against heat losses should be adequate to maintain the desired concrete temperature at all points in the structure and for the full time required.

Methods vary with type of structure and exposure. Wet burlap, heavy beds of straw—plus canvas cover-

(Above) Elevation of double-track Louisville & Nashville R. R. 6300 ft. over five busy streets in Louisville industrial section progressed rapidly, even in sub-freezing weather. 'Incor' was used for 49,500 ft. of 24-in. octagonal piles. Lengths varied, largest pile weighed 15 tons. By curing in one-fifth the usual time, 'Incor' made possible a compact, economically operated casting yard. Piles were removed from forms in 48 hours, so fewer forms were needed. Low-pressure steam curing costs were cut to bone.

Olympic-size swimming pool (right) at State Teachers' College, Springfield, Mo., was concreted with 'Incor' in February and March—when early strength pays big dividends. Despite bad weather, forms were stripped in 24 hours—saving two form-sets, worth $300 a set. And watertight curing in 24 to 48 hours with 'Incor', instead of 7 to 10 days, is a sound assurance of strong, dense, impervious concrete.

ings in cold, windy weather—are used effectively to protect highway pavements and even mass structures.

Canvas enclosures containing heating apparatus, such as perforated steam pipes or salamanders, are used for bridges, buildings and similar structures. Well-made forms help to provide some insulation against heat loss, but in cold weather must be supplemented as indicated above.

Care should be exercised to protect exposed portions of small or moderate mass and exterior vertical surfaces. Pilasters, especially at corners, lintels, buttresses and other exposed members, require extra protection and their own sources of heat in freezing weather.

Don't skimp on heat. Remember, adequate temperatures maintained for a full day, are better than inadequate temperatures for several days. Guard against temperature drops—the low point before dawn and the unexpected change in weather.

Do not suddenly expose hardened concrete to low temperatures; in extremely cold weather, allow concrete temperature to decrease slowly, until it is approximately the same as atmospheric temperature, before protection is removed. In extremely cold weather, this may mean 2 or 3 days of tapering off, depending upon the mass of the structure.

8. *Curing:* Concrete has to be kept moist in order to cure—in Winter as well as Summer. If heat is supplied by wet steam, sufficient curing moisture is usually available. If dry heat is used (salamanders, etc.), be careful to avoid drying out. Dried-out concrete will not gain in strength as it should. If air is dry, water should be applied to the concrete.

9. *Chemicals or accelerators:* Salts to lower the freezing point and chemicals designed to raise temperatures are not recommended. Calcium chloride can be used to increase rate of hardening, but should not exceed 2% by weight of the cement. More dependable results are obtained at lower cost by heating materials.

10. *Don't take chances:* It pays to be on the safe side; don't take chances simply because you may know of successful concreting in cold weather without proper protection. It is true that frozen concrete has hardened after thawing; but that's taking chances, which may lead to expensive repairs.

The additional expense necessary to make certain that cold weather does not affect the strength of the concrete is so small that it doesn't pay to neglect the simple precautionary measures.

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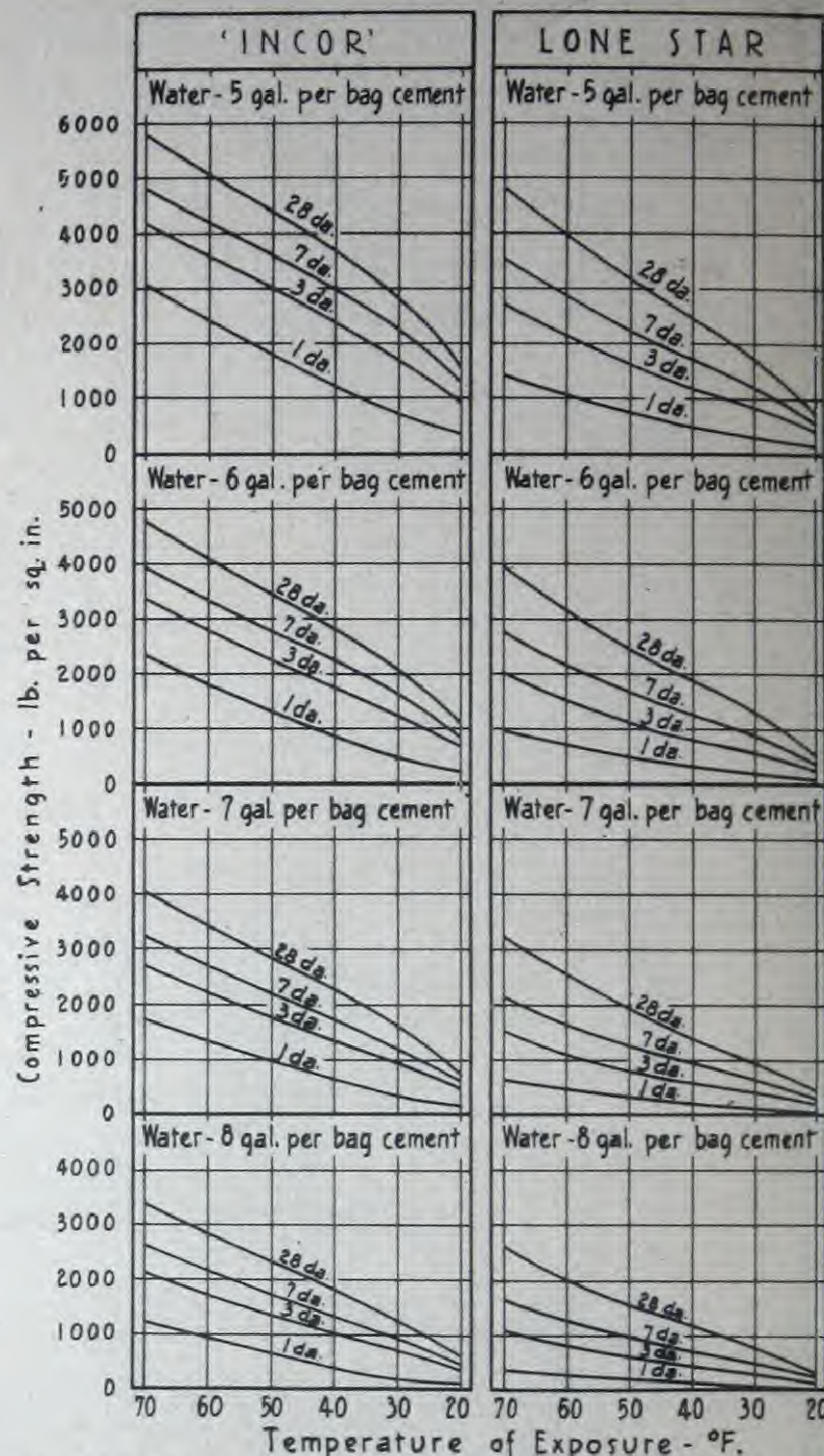
APPROXIMATE EFFECT OF

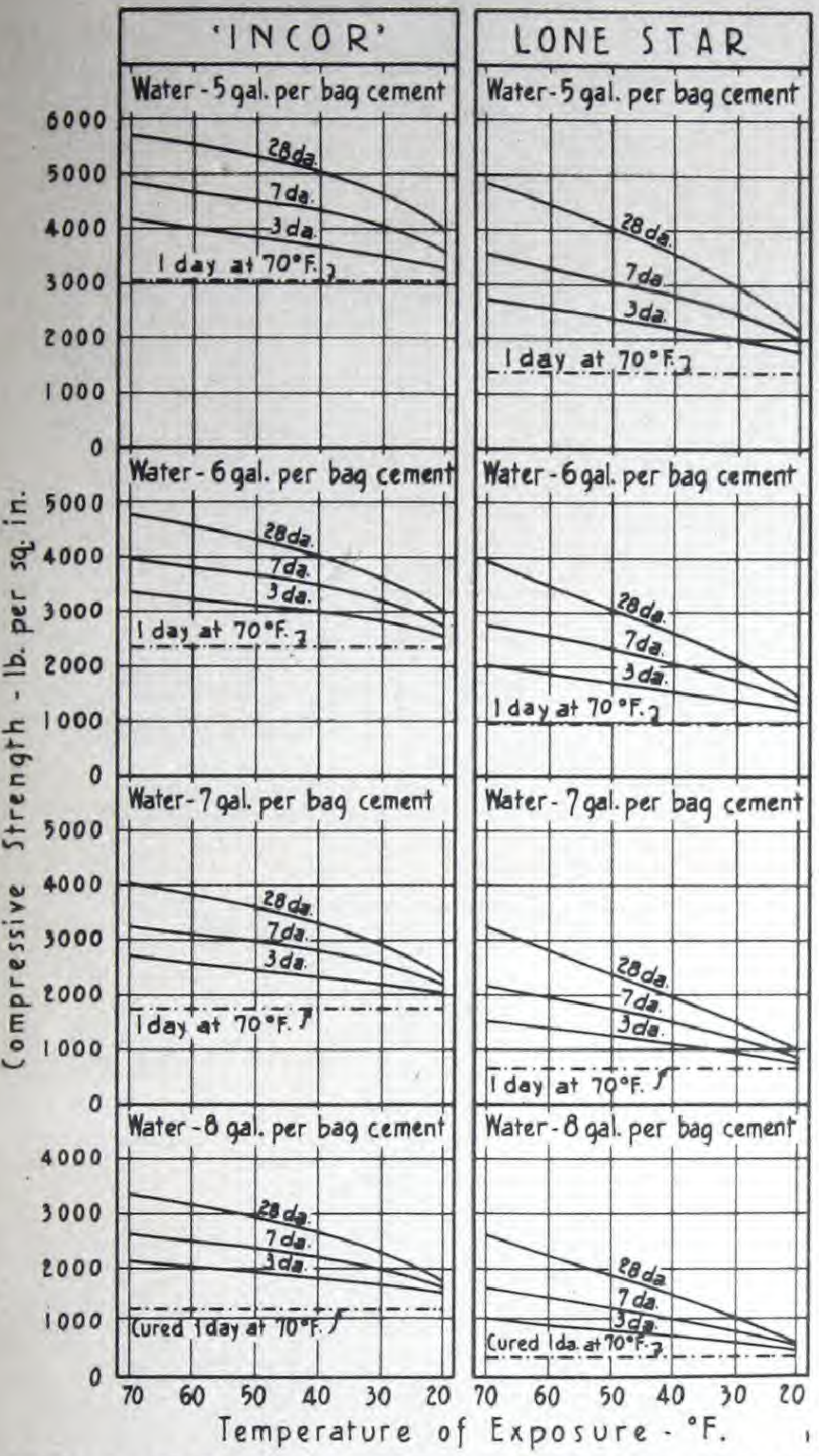


6 HOURS' HEAT PROTECTION AT 70° F

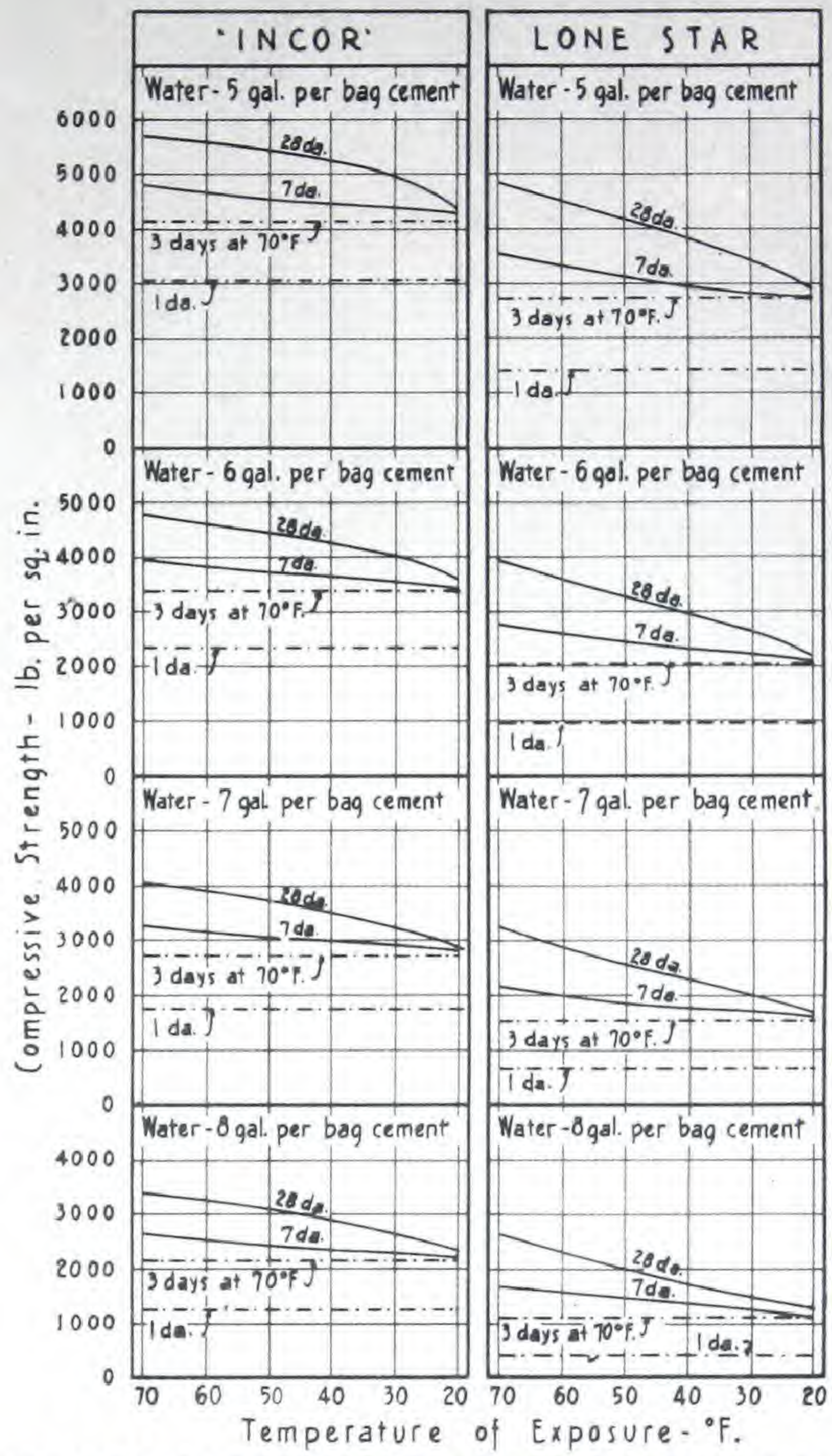
THREE graphs (above) indicate strengths which ma be expected when concrete, heated and deposited i the forms at 70°, is exposed to sub-normal temperature after heat protection for 6 hours, one day and 3 days respectively.

Six-hour heat protection corresponds to inadequat overnight curing; the graph clearly indicates its effect upo strength. Also note that 1- and 3-day strengths obtaine as a result of adequate heat protection are unaffected b air temperatures. Both cements are retarded by exposur to low temperatures, the difference being that with one day heat protection 'Incor' produces service strength making further heat protection unnecessary.

TEMPERATURES ON COMPRESSIVE STRENGTH OF CONCRETE



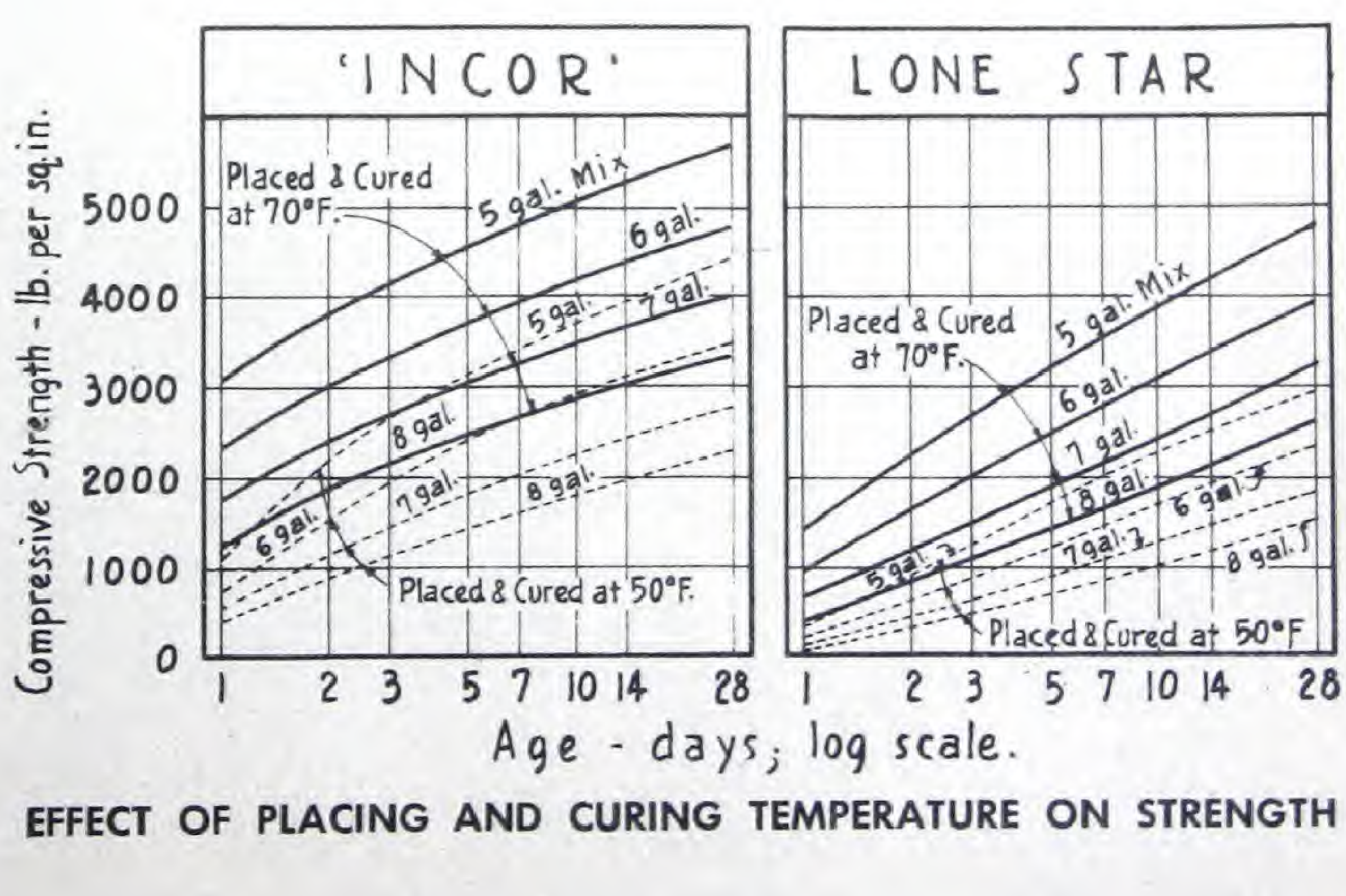
ONE DAY'S HEAT PROTECTION AT 70° F.



3 DAYS' HEAT PROTECTION AT 70° F.

These graphs assume that aggregates are heated and that concrete is deposited in forms at a temperature of not less than 70°. The effect of lower placing temperatures is shown in graph (right) of the age-strength development of 5 concretes when placed and exposed at normal temperatures of 70°, as compared with the same concretes placed and exposed at 50°. Thus, 2000-lb. strength is obtained with a 6-gal. 'Incor'* mix in less than one day when placed and cured at 70°; but it takes the same mix 3 days to attain 2000 lbs. at 50°. Similarly, with a 6-gal. Lone Star mix, 2000 lbs. is attained in 3 days at 70°, but it takes over 14 days to develop the same strength at 50°.

*Reg. U. S. Pat. Off.



EFFECT OF PLACING AND CURING TEMPERATURE ON STRENGTH